Current & Future Microwave Constellation

Jeff Hawkins, Kim Richardson, Tom Lee

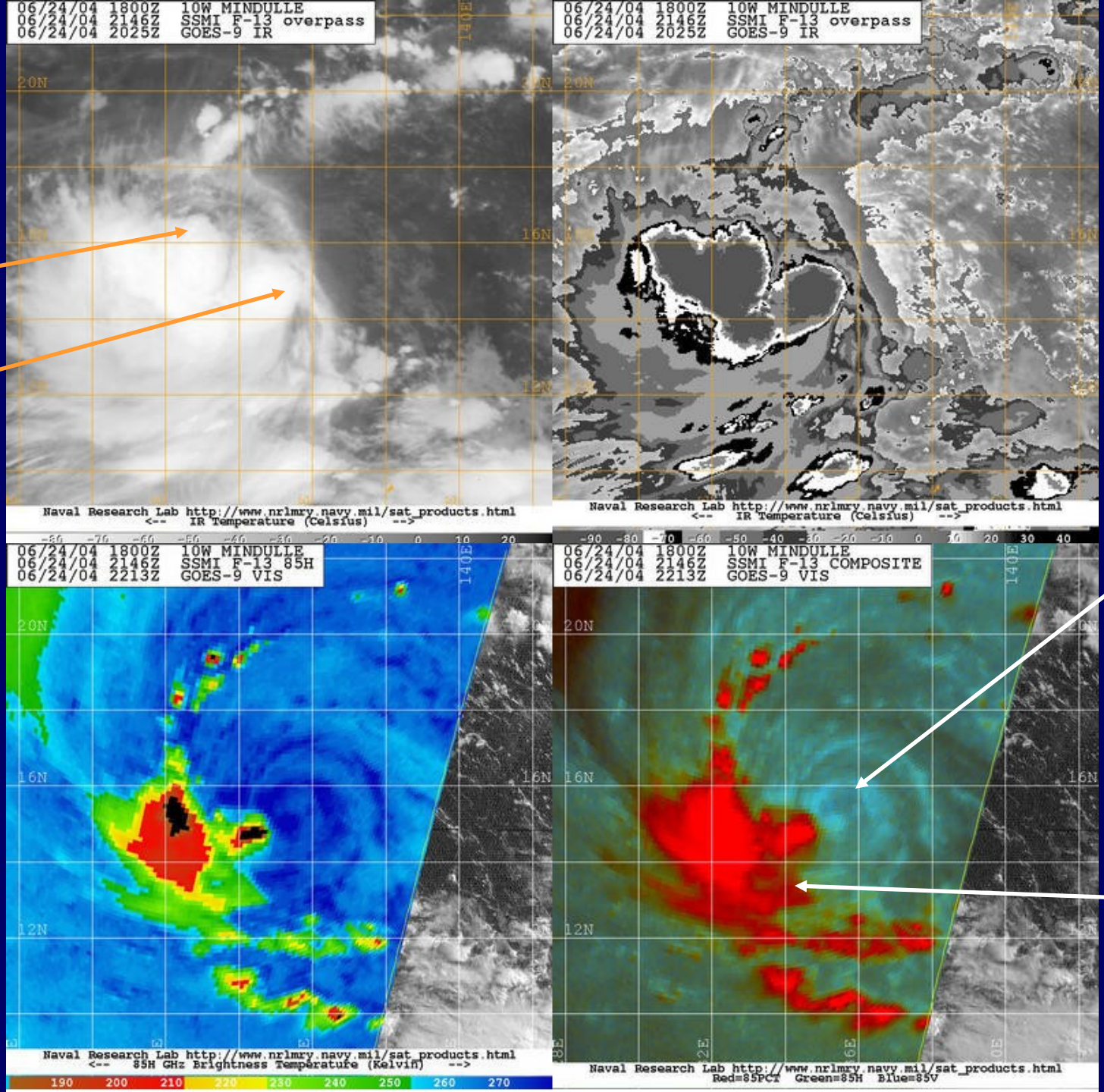
Organizations:

[1]Naval Research Laboratory, Monterey, CA 93943

Sponsors:

Office of Naval Research (ONR)
SPAWAR PEO C4I&Space/PMW-120

April 28, 2009



Apparent LLCC

True LLCC

Exposed LLCC

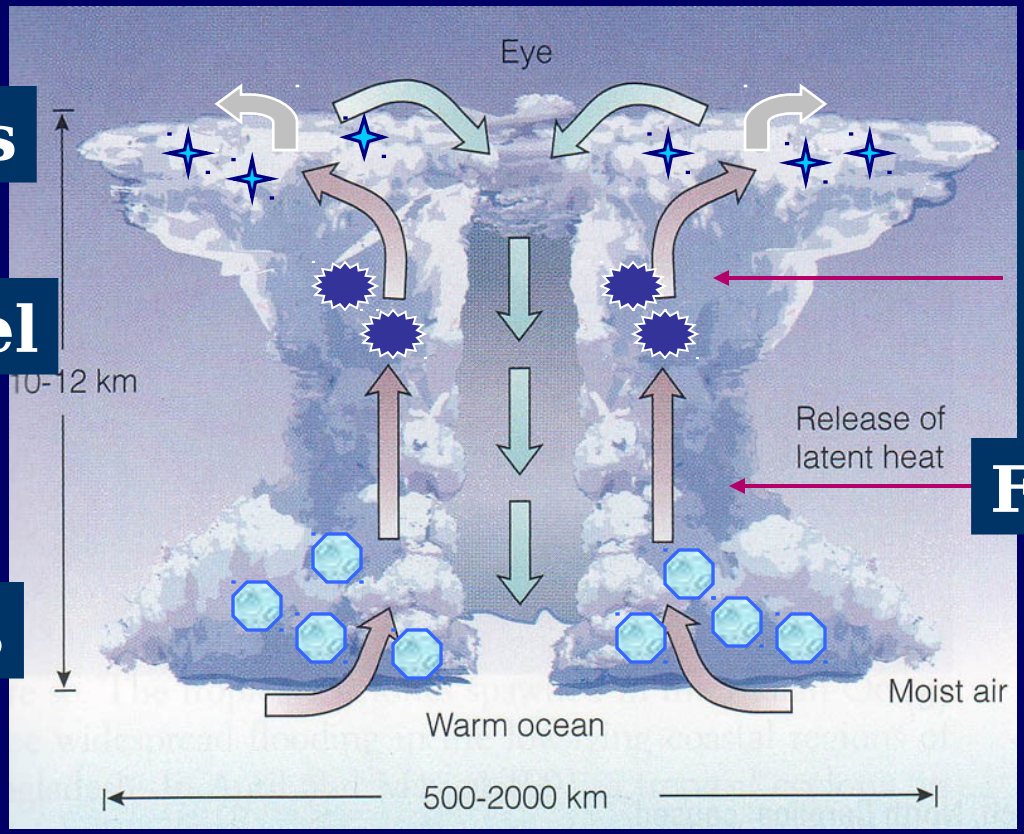
Sheared Convection

Tropical cyclone microphysics

Ice Crystals

Hail/Graupel

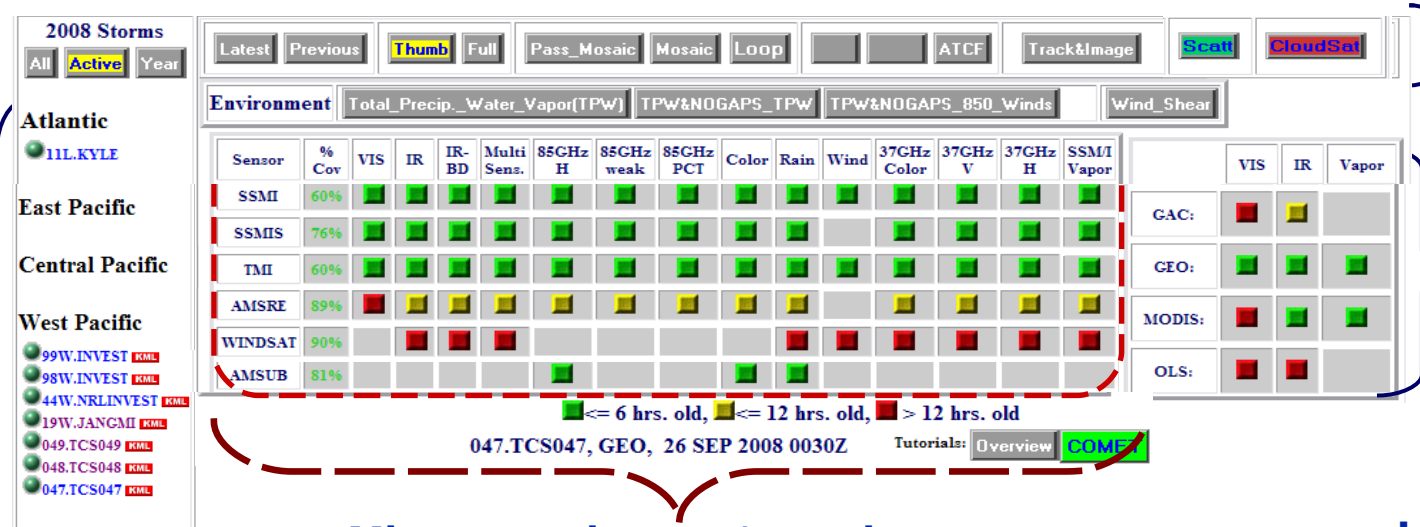
Raindrops



Effective Level of hydrometeors

Freezing level

NRL TC Web Resource

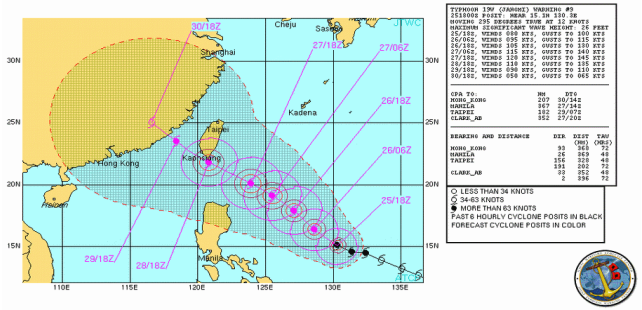


Storm Basins & Names

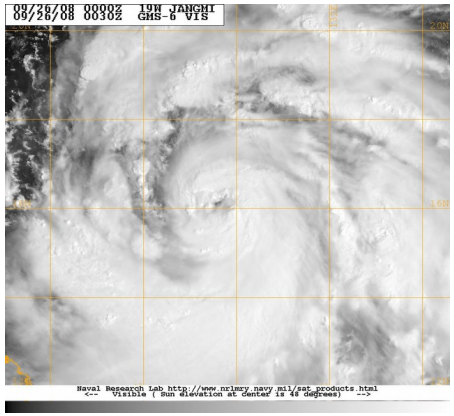
Scatterometer & CloudSat

Vis/IR imagery suite

Microwave imager/sounder product suite



Automated Tropical Cyclone Forecasting (ATCF) System warning graphic



Latest 1-km Visible/IR imagery (GEO/LEO)

30 minute MTSAT refresh with AVHRR/OLS as available

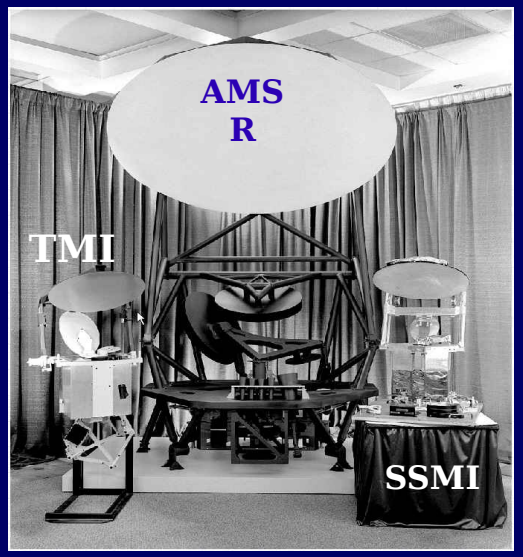
NRL TC Satellite Web Team

Special Sensor Microwave/Imager (SSM/I)

Sensor: Passive Microwave Conical Scanner
Spacecraft: DMSP – DOD Polar Orbiter
Launch: August 1987
Heritage: SeaSat Scanning Multi-channel Microwave Radiometer

Channels: 19, 22, 37, 85 GHz
55, 55, 35, 13 km

Swath: 1405 km



Enhancements for TC Applications:
(1) 1st operational microwave imager,
(2) See through non-raining clouds,
(2) Ocean surface wind speeds,
(3) Rainrates.

Web Links: http://www.ngdc.noaa.gov/dmsp/sensors/ssmi.html

TMI - TRMM Microwave Radiometer

Sensor: Passive Microwave Conical Scanner
Spacecraft: Tropical Rainfall Measuring Mission - TRMM
Launch: Nov 27, 1997
Heritage: SSM/I

Channels: 11, 19, 21, 37, 85 GHz
50, 24, 20, 12, 5 km

Swath: 750-878 km

Enhancements for TC Applications:

(1) Low orbit (~400 km provides great r
(2) Spatial resolution (36 GHz),
(2) Non sun synchronous, samples diur
(3) Sea surface temperature (SST),
(3) High winds closer to intense rain.

Web Links: http://trmm.gsfc.nasa.gov/overview_dir/tmi.html

Advanced Microwave Scanning Radiometer AMSR-E

Sensor: Passive Microwave Conical Scanner
Spacecraft: EOS Aqua, ADEOS-2
Launch: May 2002, Dec 2002
Heritage: TMI, SSM/I

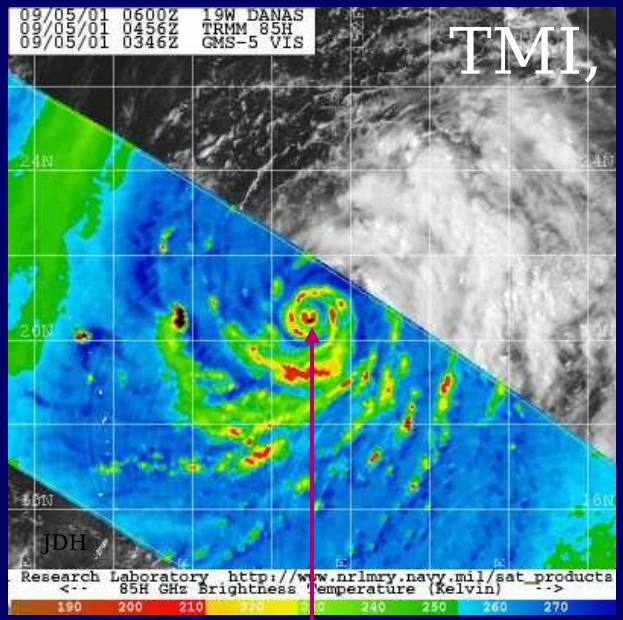
Channels: 6, 10, 18, 23, 36, 89 G
50, 50, 25, 25, 15, 5

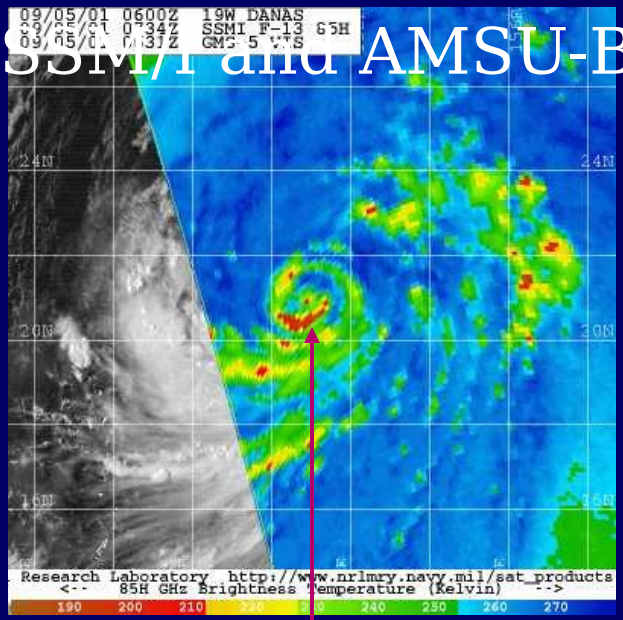
Swath: 1600 km (1450 – AMSR)

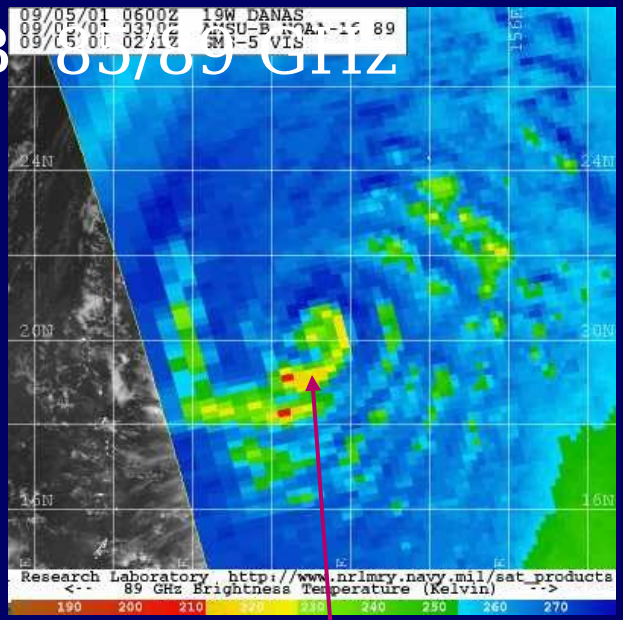
Enhancements for TC Applications:
(1) Huge 2 m dish provides superb
(2) Spatial resolution (36 GHz),
(2) Best swath with high resolution
(3) Sea surface temperatures.

Web Links: http://www.ghcc.msfc.nasa.gov/AMSR/
http://eos-pm.gsfc.nasa.gov/

Resolution, Resolution, Resolution!







TMI, SSM/I and AMSU-B 85/89 GHz

Small, intense eye with secondary eyewall developing.

Small inner eye just visible, while secondary eyewall the main feature as reduced resolution.

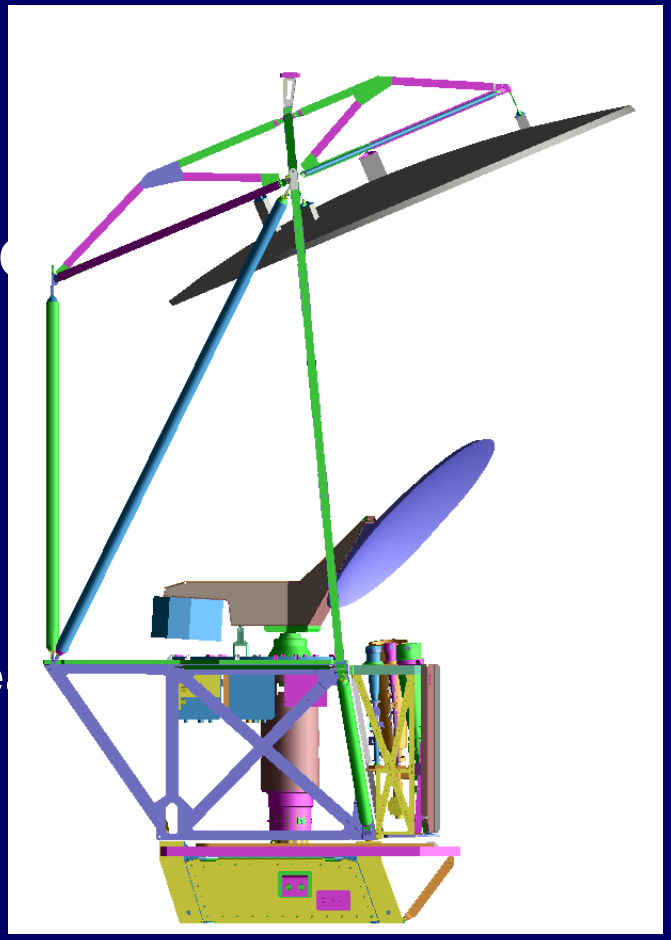
Inner eye not viewable, secondary eyewall difficult to full identify.

WINDSAT

Sensor: Passive Microwave Conical Scanner
Spacecraft: Coriolis
Launch: 2003 (January)
Heritage: SSM/I

Channels: 7, 11, 19, 24, 37, No 85 (
~55, 40, 20, 13, 11,

Swath: 1025 km



Enhancements for TC Applications:

(1) Prelude to NPOESS MIS,
(2) Surface wind vectors, non-rain are
(3) Spatial resolution (37 GHz),
(4) Sea surface temperature

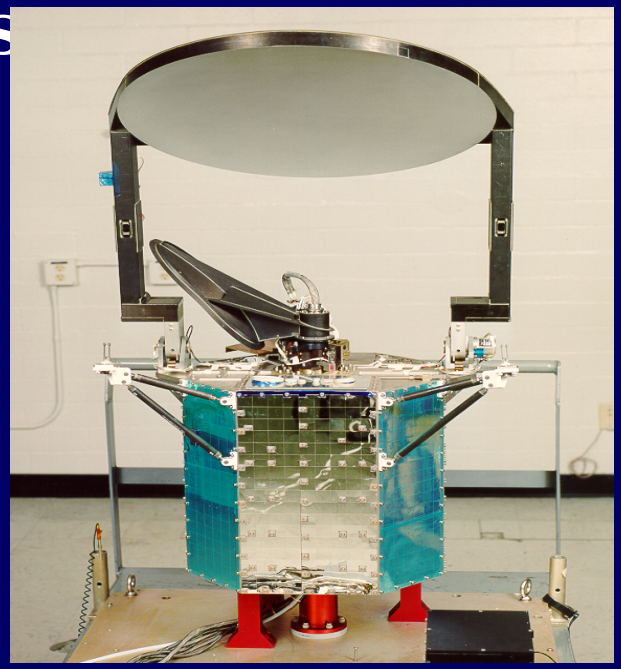
Web Links: http://www.pxi.com/windsat.main.html

Special Sensor Microwave Imager Sounder (SSMIS)

Sensor: Passive Microwave Conical S
Spacecraft: DMSP F-16, 17, 18, 19, 20
Launch: May 2003
Heritage: SSM/I, T1, T2

Channels: 19, 22, 37, 91 GHz
~55, 55, 35, 12 km

Swath: 1700 km



Enhancements for TC Applications:

(1) Longevity: 5 sensors [2003-2016],
(2) Collocated imager/sounder channels, improved retrievals,
(3) Large swath

Web Links:

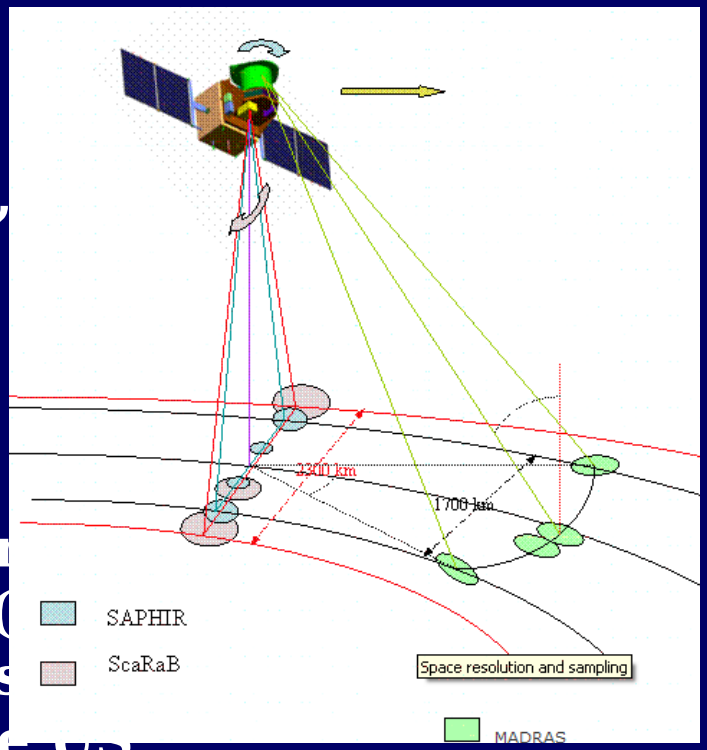
http://www.osdpd.noaa.gov/PSB/IMAGES/ssmisdoc.htm

MicroWave Radiation Imager (MWRI) – FY-3A/B

Sensor: Passive Microwave Conical Scanner
Spacecraft: FY-3A, 3B (China)
Launch: May 2008, 2010
Heritage: SSM/I-like

Channels: 10.65, 18.7, 23.8, 36.5, 89,
~80, 50, 45, 30, 15,

Swath: 1400 km



Enhancements for TC Applications:

(1) Sequence of four (4) launches, co
(2) Data latency good, seven stations (
(3) Currently experiencing technical is
(4) Some test data sets available in the US

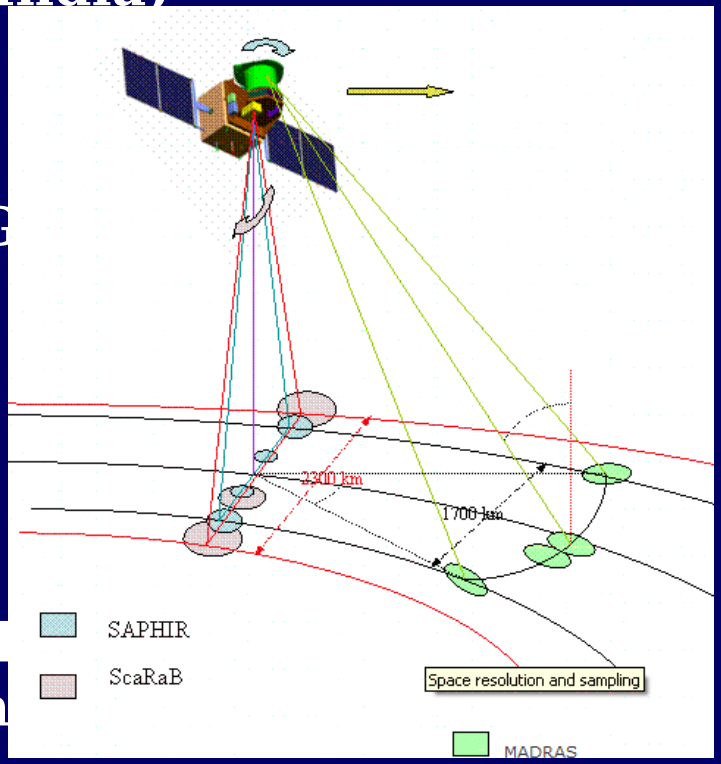
Web Links: http://dragoness.nersc.no/?q=system/files/DRAGONESS_D2.1.doc

MADRAS – Mega Tropiques

Sensor: Passive Microwave Conical Scanner
Spacecraft: Mega-Tropiques (France-India)
Launch: Early 2010
Heritage: TMI

Channels: 18.7, 23.8, 36.5, 89, 157 G
~40, 40, 40, 10, 6 km

Swath: 1700 km

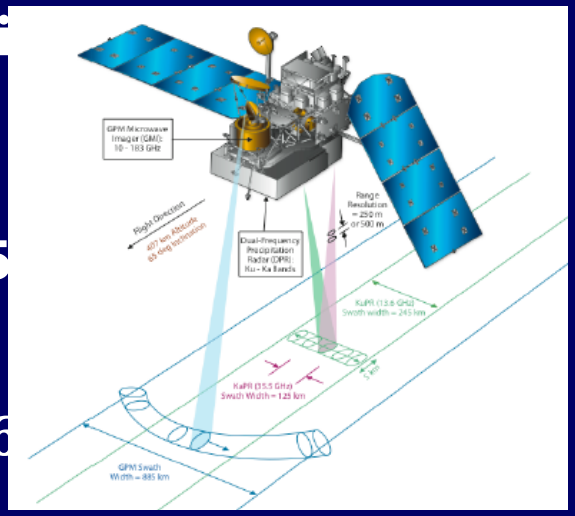


Enhancements for TC Applications:
(1) Tropical inclination (20 deg),
(2) Good TC coverage while in tropical
(3) Data latency, additional stations in

Web Links: http://meghatropiques.ipsl.polytechnique.fr/

Global Precipitation Mission - GPM

Sensor: Passive Microwave Conical Scanner/Precipitation Radar
Spacecraft: GPM
Launch: Core (July 2013), Low inclinati
Heritage: TRMM TMI-PR



GPM Microwave Imager (GMI)

Channels: 10.6, 18.7, 22.8, 36.5, 89, 165.5
~26, 15, 12, 11, 6, 6,

Swath: 885 km (GMI), 125-245km (35-13.6

Enhancements for TC Applications:

(1) Tropical (40 deg) and higher inclination (65 deg, non sun sync),
(2) Superb TC coverage while in tropical belt,
(3) Dual frequency radar (enhanced rainrates, especially < 10 mm/hr)
(4) Reference standard for other microwave imagers

Courtesy: Hou

Global Precipitation Mission - GPM

Passive Microwave Sensor Characteristics in the GPM Era

Constellation microwave sensor channel coverage

V – Vertical Polarization H – Horizontal Polarization

Channel	6 GHz	10 GHz	19 GHz	23 GHz	31/36 GHz	50-60 GHz	89/91 GHz	150/166 GHz	183/190 GHz
AMSR-E	6.925 V/H	10.65 V/H	18.7 V/H	23.8 V/H	36.5 V/H		89.0 V/H		
GMI		10.65 V/H	18.70 V/H	23.80 V	36.50 V/H		89.0 V/H	165.5 V/H	183.31 V
MADRAS			18.7 V/H	23.8 V	36.5 V/H		89.0 V/H	157 V/H	
SSMIS			19.35 V/H	22.235 V	37.0 V/H	50.3-63.28 V/H	91.65 V/H	150 H	183.31H
MHS							89 V	157 V	183.311 H 190.311 V
ATMS				23.8	31.4	50.3-57.29	87-91	164-167	183.31

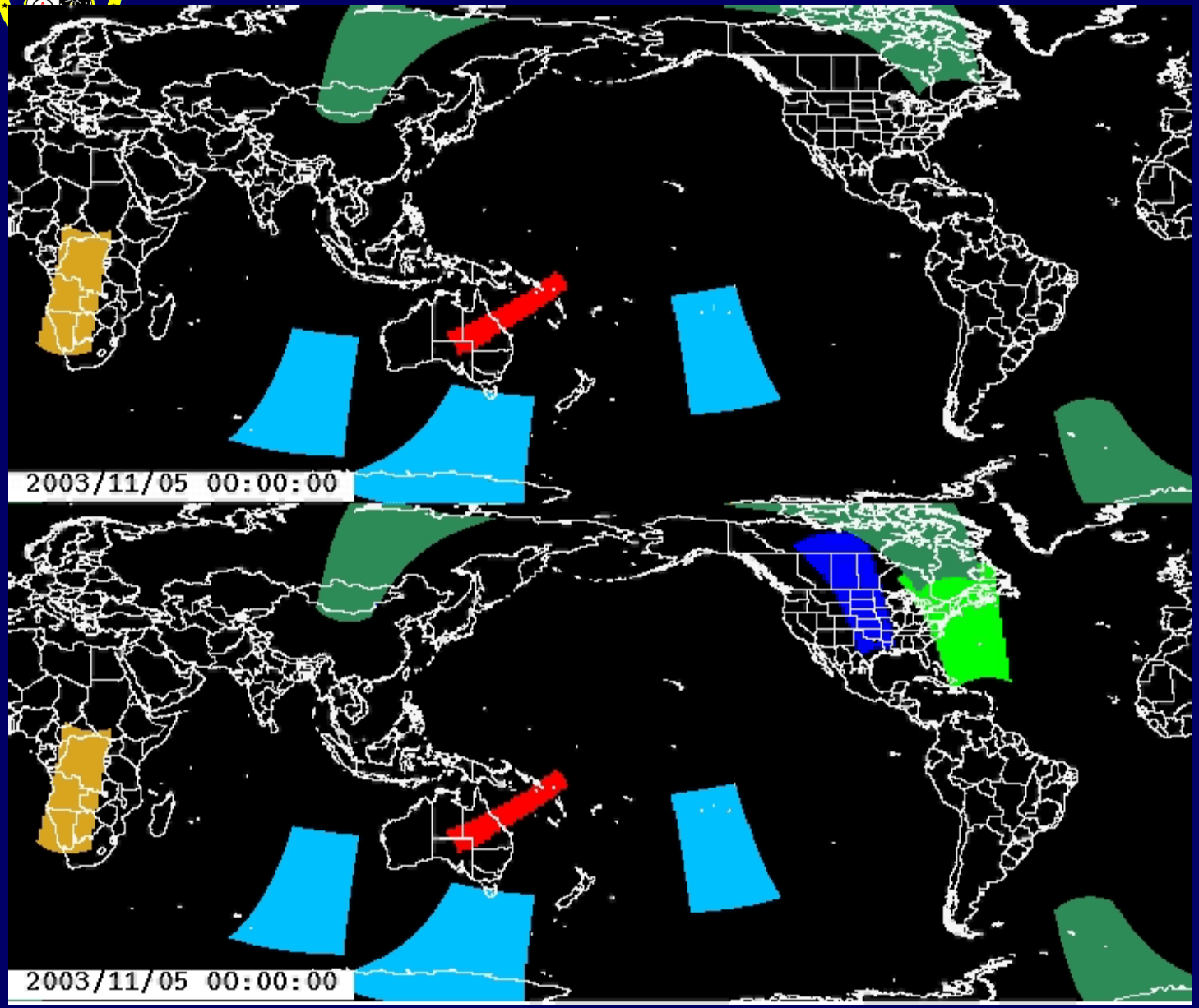
Mean Spatial Resolution (km)

Channel	6 GHz	10 GHz	19 GHz	23 GHz	31/36 GHz	50-60 GHz	89/91 GHz	150/166 GHz	183 GHz
AMSR-E	56	38	21	24	12		5		
GMI		26	15	12	11		6	6	6
MADRAS			40	40	40		10	6	
SSMIS			59	59	36	22	14	14	14
MHS							17	17	17
ATMS				74	74	32	16	16	16

Different center frequencies, viewing geometry, and spatial resolution must be reconciled

Courtesy: Hou

urrent (10-Satellite) Constellation Revisit Tim



8-satellites
SSMI
DMSP F-13/14/15
AMSR-E
Aqua
AMSU-B
NOAA-15/16/17
TMI
TRMM

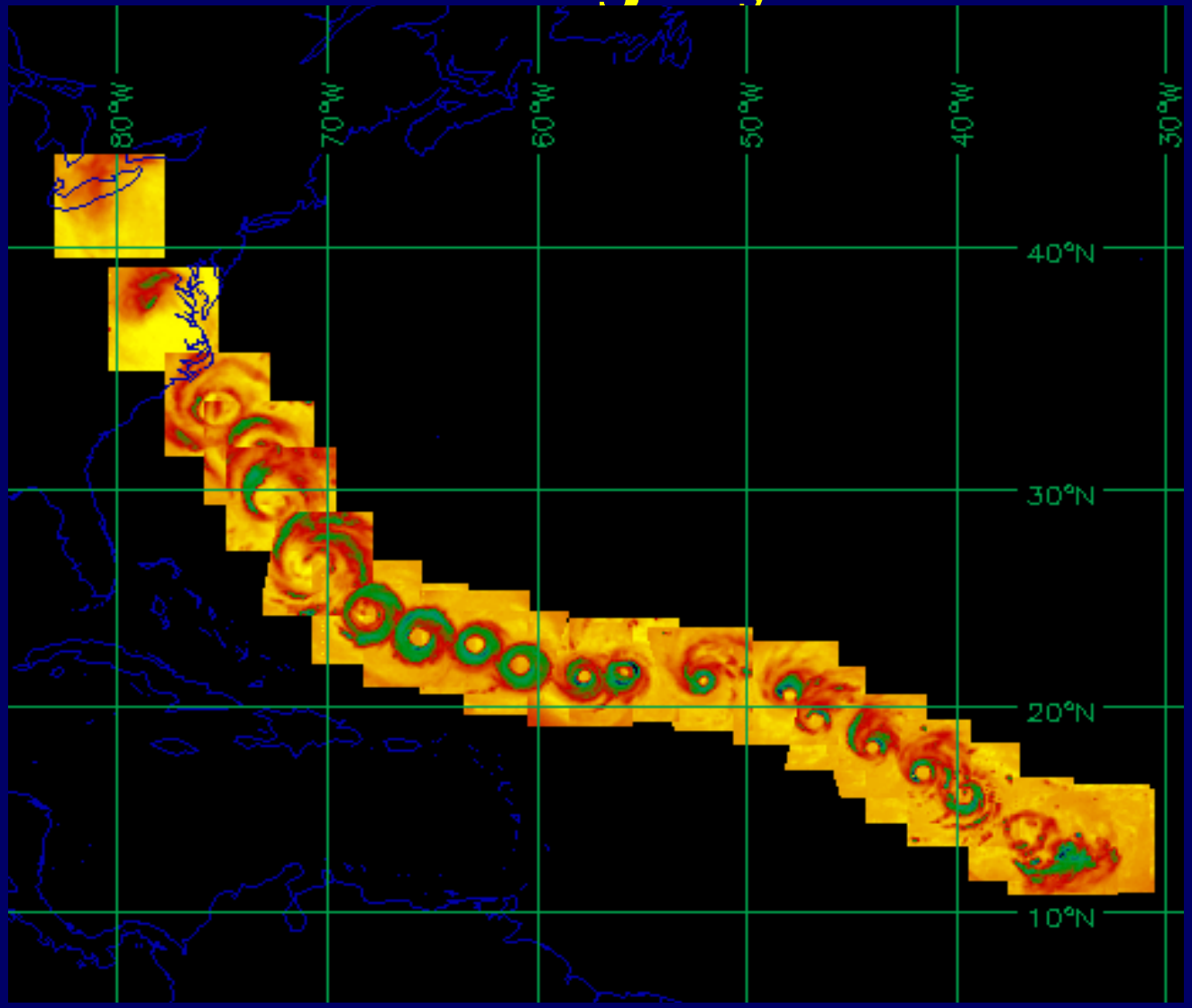
10-satellites
Coriolis
Windsat
SSMIS
F-16

10+

0 1 2 3 4 5 6 7 8 9 10

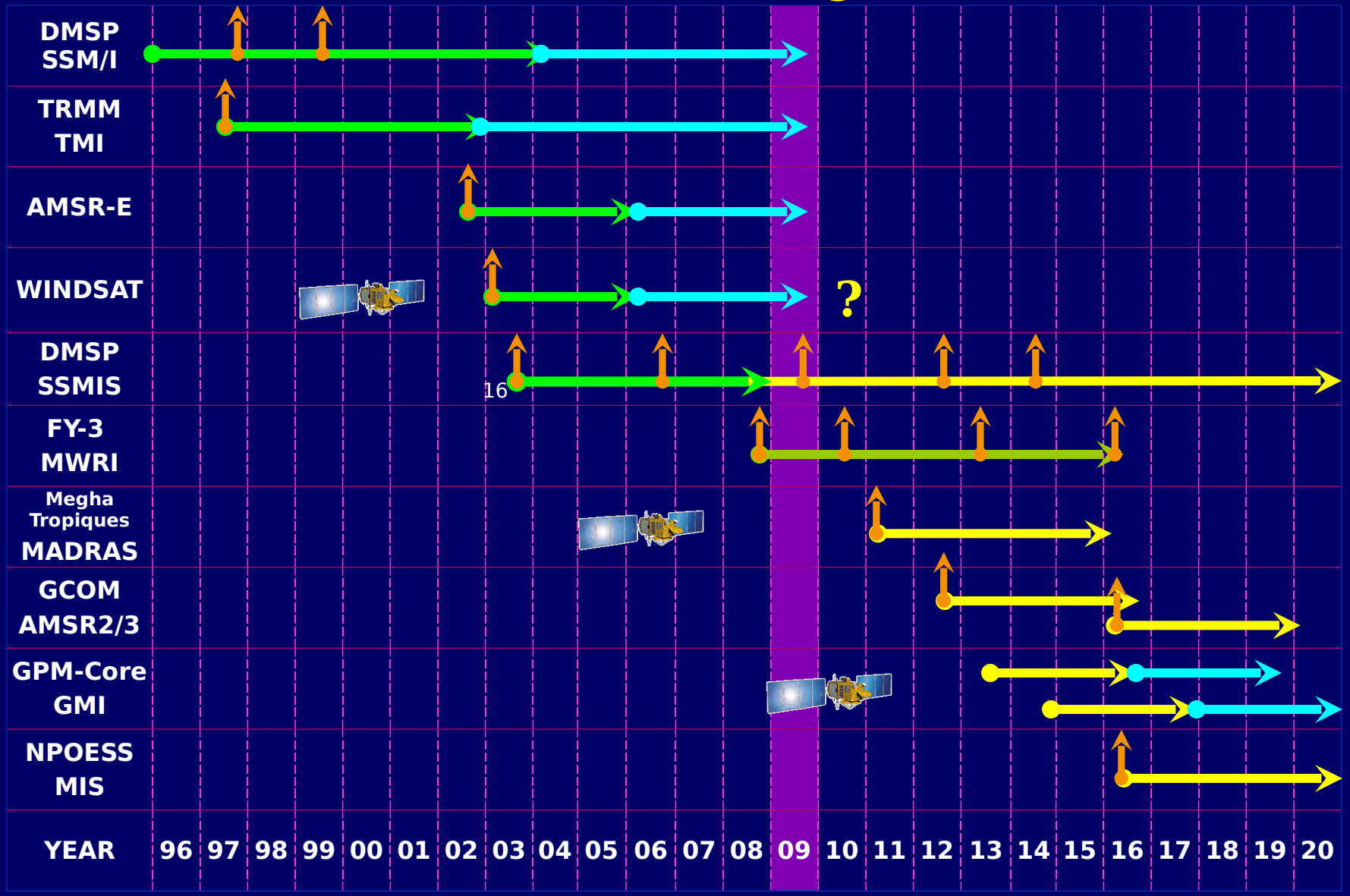
evisit Scale: White= 0 hours Black= 6+ hours (shaded boxes represent 15-

Passive Microwave Imagery



Hurricane Isabel 85 GHz

Passive Microwave Imager Missions



Primary mission

Launches

Projected extended mission

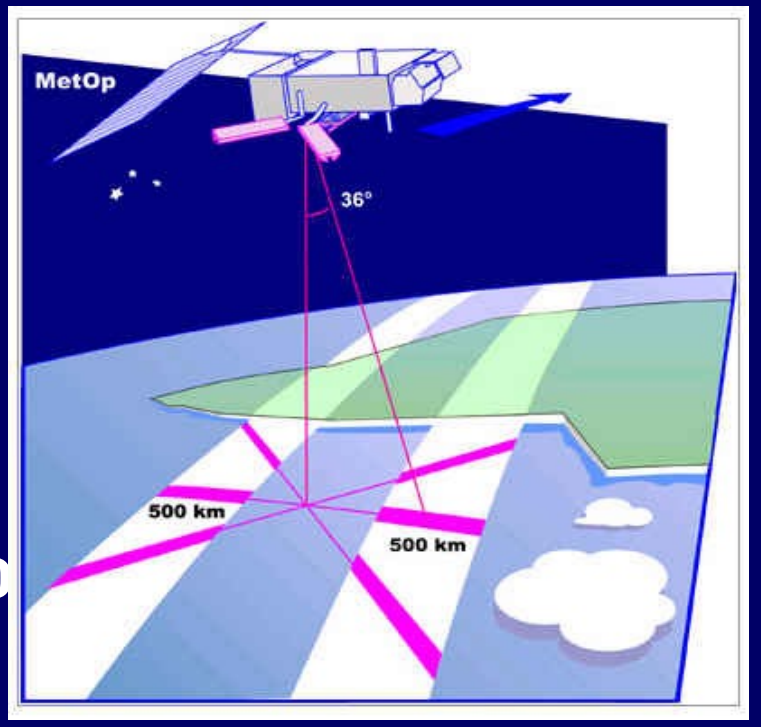
Future

April 2009
Hawkins-Hou-Ferraro

Advanced SCATterometer (ASCAT)

Sensor: Microwave radar
Spacecraft: MetOp-1, 2, 3
Launch: 2006, 2010, 2015
Heritage: ERS-1, 2

Channel: 5.25 GHz, C-band.



Swath: Two 520 km swaths, with 700

Enhancements for TC Applications:

(1) Only long term operational scatterometer series,
(2) C-band, less rain contamination, larger footprint,
(3) 25 and 50-km wind vector products, good for gale force winds,
(4) Gap in swath center is a major drawback.

Web Links: http://www.esa.int/export/esaMF/ascat.html

Dual Frequency Scatterometer (DFS – GCOM)

Sensor: Microwave radar
Spacecraft: GCOM – Global Change Observation Mission
Launch: 2012
Heritage: QuikSCAT

Channel: 5.4 & 13.4 GHz (C & Ku band)

Swath: 1800 km

Enhancements for TC Applications:

(1) Dual frequency/pol mitigates many rain issues,
(2) Maintains QuikSCAT's huge swath,
(3) 40% better than QuikSCAT, clear sky > 20m/s
(2) Extends usable winds to ~ 90 kt

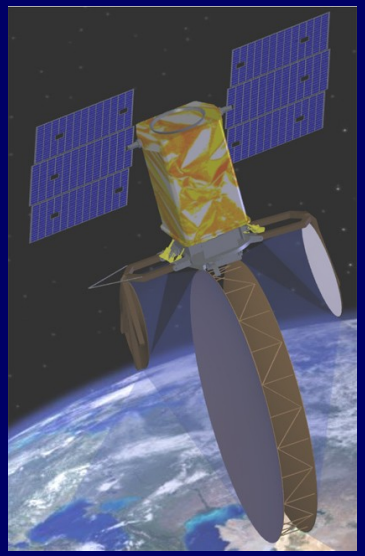
Web Links: http://www.esa.int/export/esaME/ascat.html

EXtended Ocean Surface Vector Wind Mission (XOVWM)

Sensor: Microwave radar
Spacecraft: XOVWM
Launch: 2020 ?
Heritage: QuikSCAT/DFS

Channel: 5.4 & 13.4 GHz (C & Ku band)

Swath: 1800 km

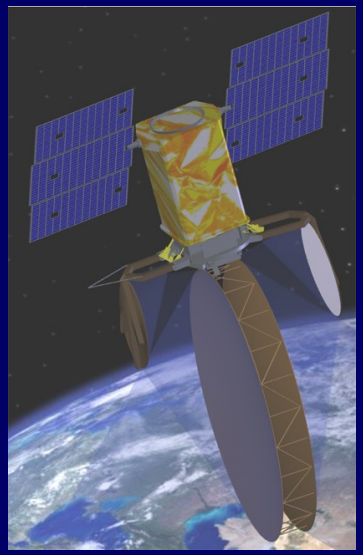


Enhancements for TC Applications:

(1) Dual frequency/pol and radiometer mitigates rain issues,
(2) Maintains QuikSCAT's huge swath,
(3) Spatial resolution (5-km) to resolve wind gradients, coasts,
(2) Extends usable winds to ~ 90 kt

XOVWM (XOVWM)

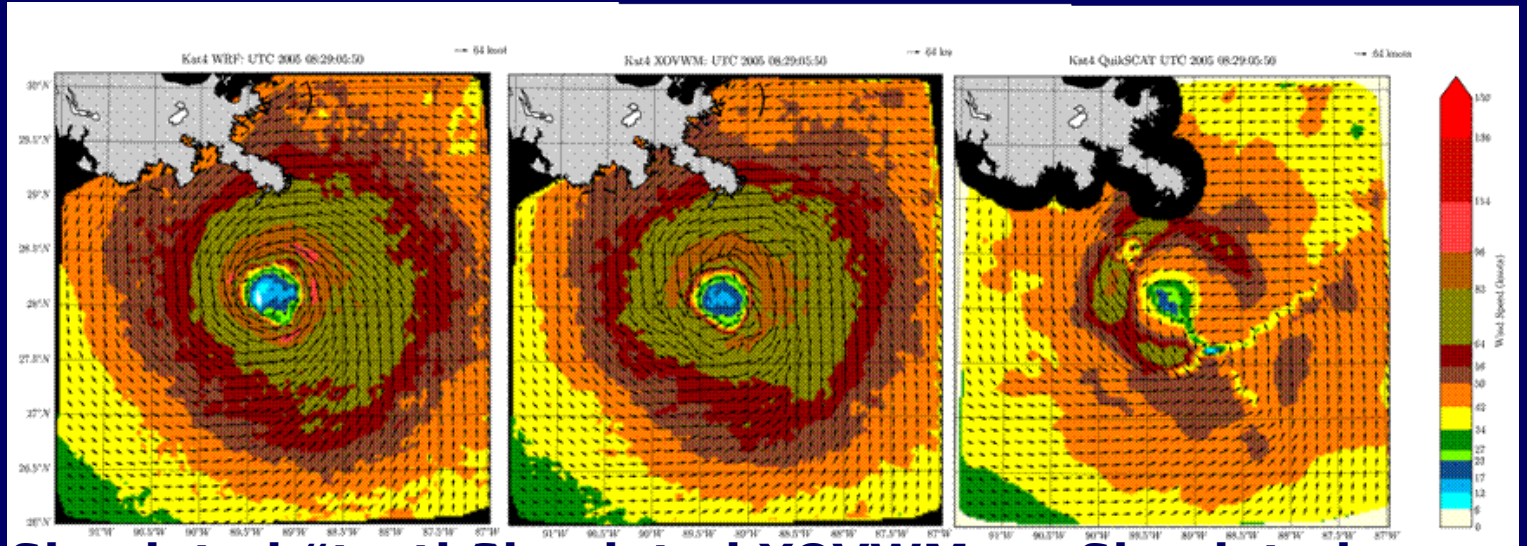
Paul Chang, NESDIS



Goal: Satisfy NOAA's operational OSVW requirements

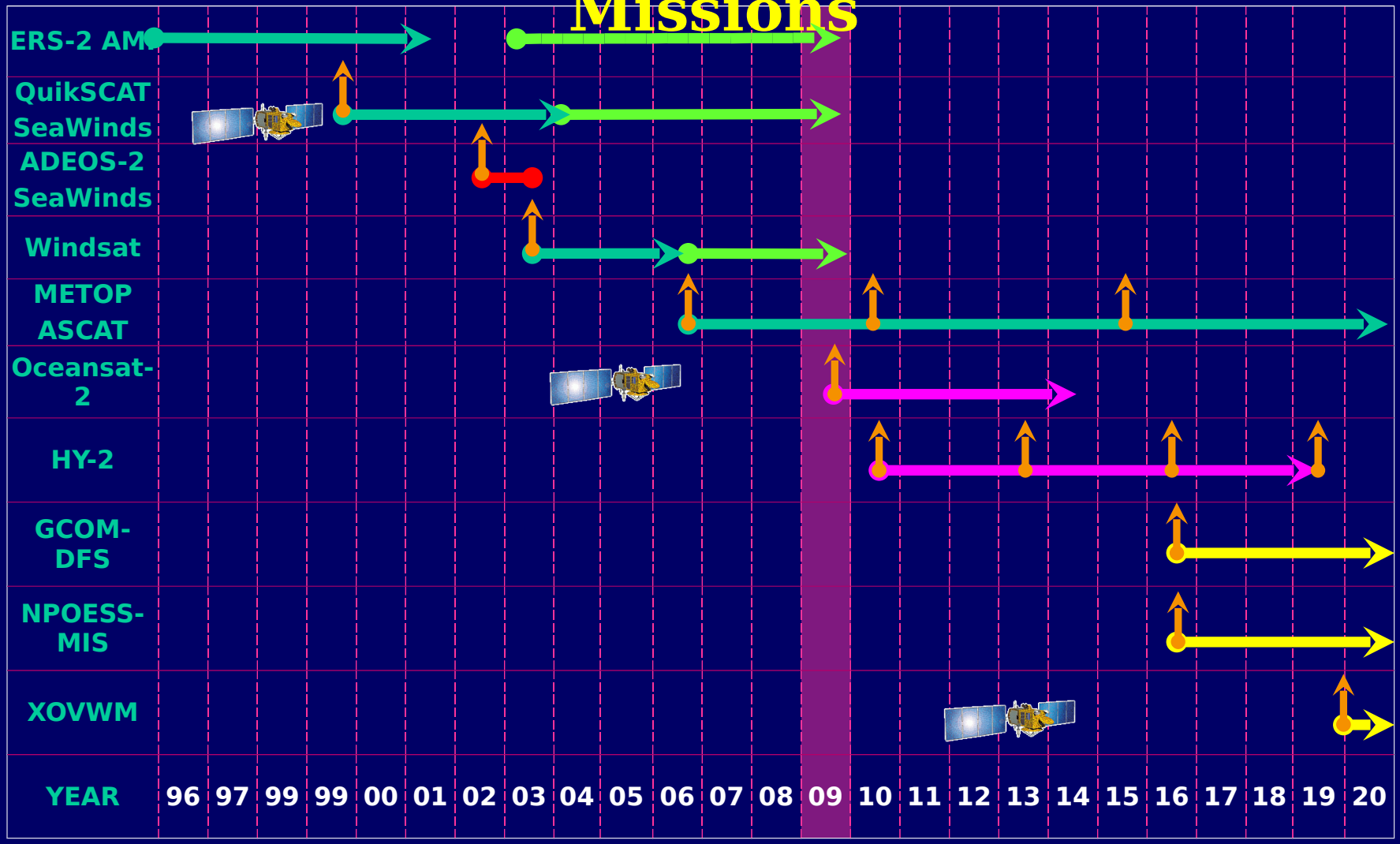
Performance Advancements:

- **Higher spatial resolution (5 km)**
- **Full wind speed range,**
- **Coastal coverage 2.5-5 km of land**
- **All - weather**



Simulated "truth" **Simulated XOVWM** **Simulated**

Scatterometer & Surface Wind Vector Missions



Primary mission

Projected extended mission

Future

Uncertain

April 2009
Chang,
Hawkins

GeoSTAR/PATH: A Future Hurricane Observing System

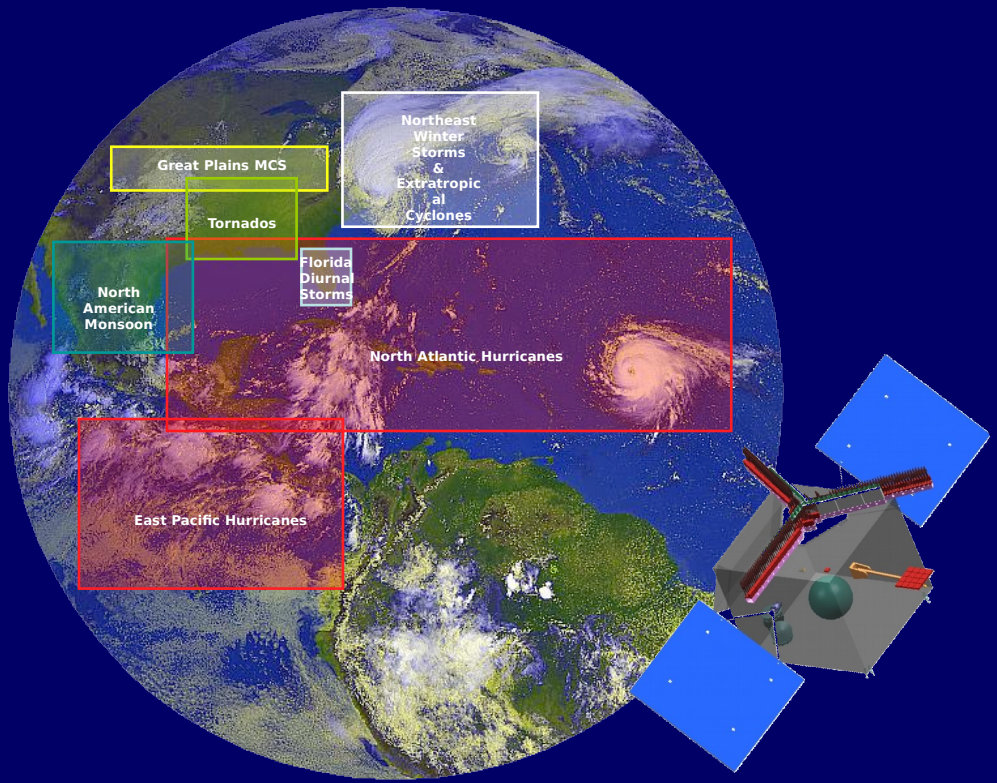
Bjorn Lambrigtsen, JPL [14B.3]

"GeoSTAR" concept: AMSU-equivalent performance from GEO

Temperature, moisture soundings, TPW, rainrate

"PATH" GEO/MW mission is identified in NRC Decadal Survey

Observational focus on hurricanes & severe storms



- **Weather forecasting**
  - Improve regional NWP; severe storms
- **Hurricane diagnostics**
  - Quintessential hurricane sensor
- **Rain**
  - Complements GPM
- **Tropospheric wind profiling**
  - NWP, transport applications
- **Climate research**
  - Hydrology cycle, climate variability

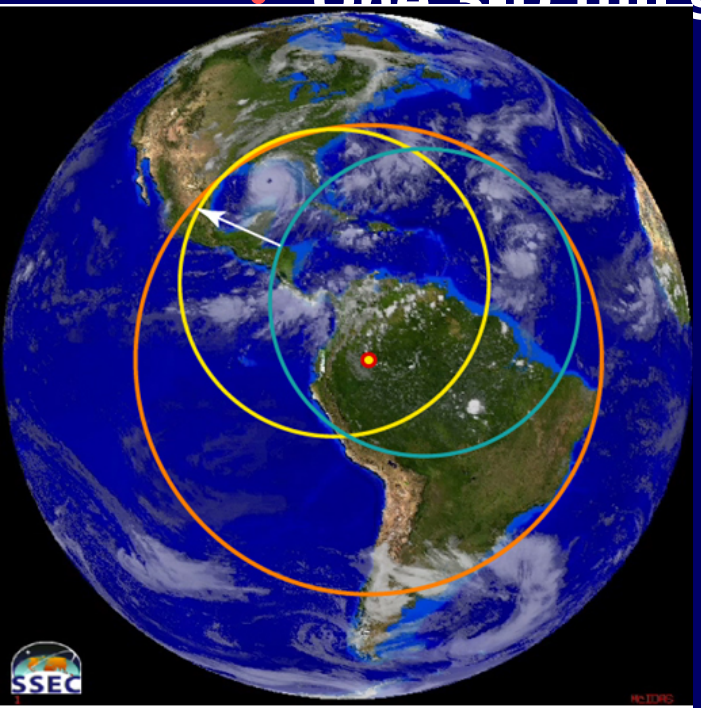
NEXRAD In Space (NIS)

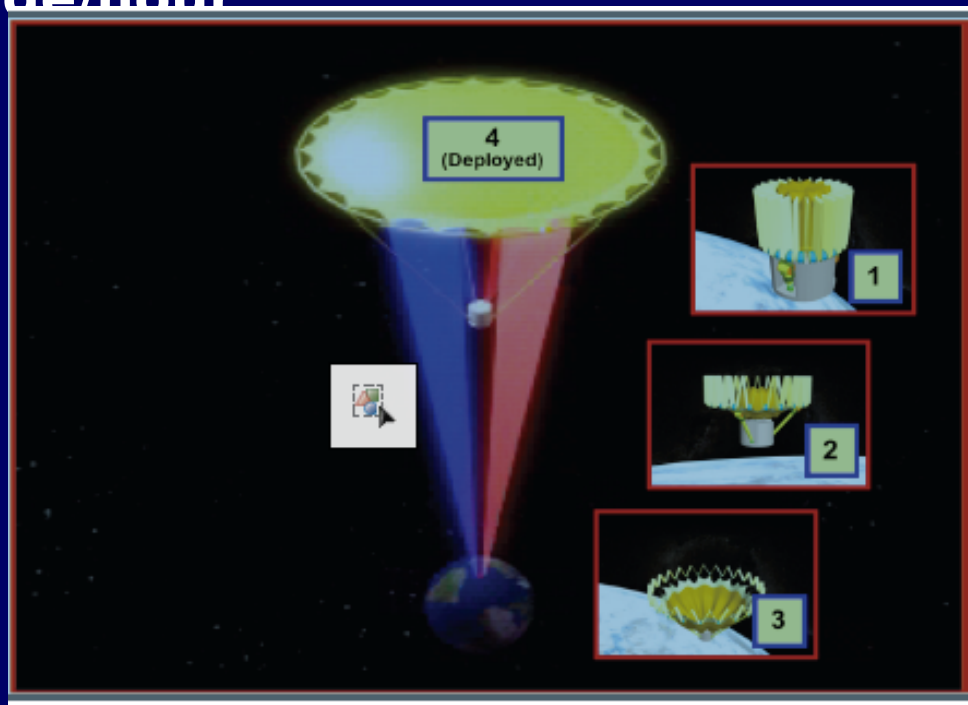
Smith/Tripoli
17B.6

Goal: Geostationary Radar Sensor

Performance Advancements

- First GEO radar sensor: Ka band (35 GHz)
- 28 m deployable antenna: 12km footprint (nadir)
- Swath = 2600 km radius
- One 3-D full scan image/hour



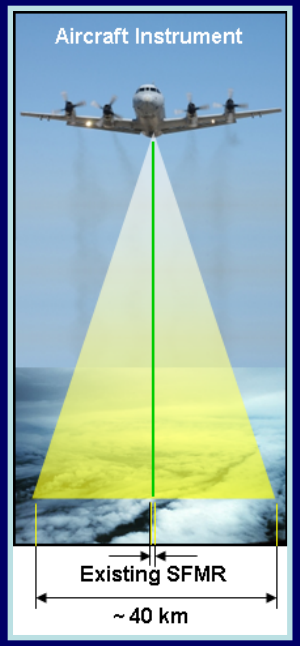


Hurricane Imaging Radiometer

NASA

HIRAD

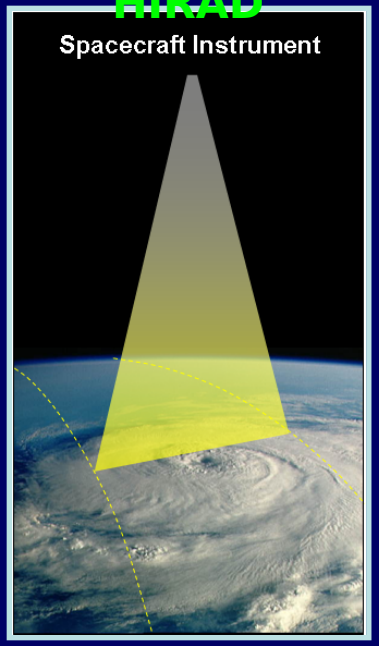
Now - SFMR



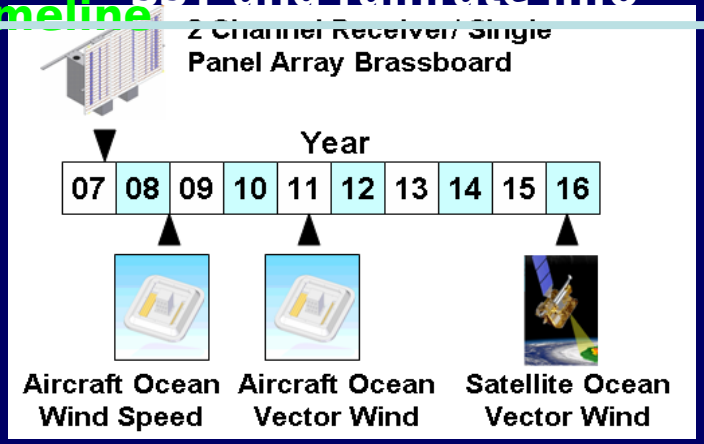
HIRAD Description

- C-band (4-7 GHz) frequencies
- Synthetic thinned array radiometer (STAR)
- Push broom imager
- Single polarization for ocean wind speed
- Dual polarization for ocean vector wind
- SST and rainrate info

Future - HIRAD



Optimal HIRAD Development Timeline



NASA NOAA

UAH U. of Alabama/Huntsville

U. of Michigan U. of Central Florida